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ABSTRACT

This publication is the first of a series of seven supplementary investigative materials for use in secondary science classes providing up-to-date research-related investigations. This unit is structured for grades 9 through 12. It is concerned with the osmatic dehydration of fruits. The guide provides students with information about food preservation techniques, particularly osmovac. The first part of this guide provides the teacher with: (1) materials needed; (2) suggestions to facilitate classrcom use for the investigations; and (3) suggested reading. The second part provides students with background information and four investigations. The investigations are based on the biological principle of diffusion through a membrane: osmosis. They are: (1) solute exploration; (2) time and water loss; (3) sugar concentration and water loss; and (4) emergency water purification. Each investigation consists of: (1) materials needed for a four-student team; (2) procedures; (3) questions for thought; (4) extending the investigations; and (5) suggested reading. (HM)

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science study aids

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SE 024 377

dehydration for food preservation

Developed by John Boeschen, a graduate student in Science Curriculum and Instruction at U. C. Berkeley. Mr. Boeschen prepared the manuscript in cooperation with Dr. James D. Ponting, Dr. Karel Popper, and Wayne M. Camirand, scientists of the Agricultural Research Service, U. S. Department of Agriculture, at the Western Regional Research Center, Berkeley, California.

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TO THE TEACHER

This Science Study Aid (SSA) is based on research conducted by ARS scientists at the Western Regional Research Center, Berkeley, California. It is concerned with the osmotic dehyration of fruits. The unit, composed of four Investigations, provides students with information designed to help them understand food preservation techniques - - in particular, Osmovac, an osmotic drying technique developed by ARS scientists.

The Investigations in this SSA are based on the biological principle of diffusion through a membrane: osmosis. The four Investigations are designed for grades 9 through 12 and are appropriate supplements to chemistry, biology, and general science courses.

Three of the Investigations help students determine the best of several variables in the osmotic-dehydration of apple slices. A fourth Investigation gives instructions for assembling an emergency water purifier.

Supplementary information for each Investigation is provided in this section to facilitate its implementation in the classroom.

MATERIALS LIST

For your convenience, the materials needed to perform all the Investigations in this Science Study Aid are listed below. The list gives the quantities needed for each four-student team.

STUDENT MATERIALS

Commercially prepared light corn syrup:

110 to 170 ml for Investigations 1 & 2
330 to 510 ml for Investigation 3

Sodium chloride (NaCl):

25 gm for Investigation 1
100 gm for Investigation 4

1/4 apple
1 paring knife
1 pair tweezers
1 balancing scale
3 jars with lids — 110 to 170 ml (4 to 6 oz.)
110 to 170 ml tap water
6 paper towels
1 large beaker
113 gm (4 oz.) concentrated orange juice
1 sheet cellulose acetate 8" x 8"
1 jar with lid - 1 litre
2 marbles

TEACHER MATERIALS

2 beakers - 1 litre
1 litre light corn syrup
1500 ml tap water

OPTIONAL

1 carrot
300 mm glass tubing 2 mm inside diameter
1 cork
1 stand for holding carrot osmometer
2 cork borers: one size of glass tubing,
one size of cork
tap water (enough to cover carrot to 3/4 of height)
sugar *
paraffin
food coloring
1 bottle strong smelling perfume or shaving lotion

(*quantity depends on volume of water)

INQUIRY LAB - CARROT OSMOMETER

Before you introduce the materials in this SSA to your students, you may want to set up the following lab and use it as a focal point for a class discussion. You will need the following materials for the carrot osmometer:

1 carrot
300 mm of glass tubing, 2 mm inside diameter
1 cork
2 cork borers
water
sugar (quantity depends on volume of water)
1 stand for holding carrot
paraffin
food coloring

1. Bore a hole in a carrot, being careful not to cut completely through side or bottom.
2. Make a 10% sugar solution (1 gm of sugar for every 10 ml of water) and darken it with food coloring. Pour the solution into the carrot, but not all the way to the top.
3. Next, insert the glass tubing into the cork and seal it with wax.
4. Place this unit into the carrot (be sure the tubing is in the sugar solution). Seal the cork into the carrot with wax.
5. Immerse the carrot, about 3/4 of its length, in a beaker containing room temperature water.

Ask your students what they think the system is all about. After a few minutes, the colored sugar solution will begin to rise in the glass tubing, due to the osmotic diffusion of water into the carrot. When this happens, see if anyone can offer an explanation. Following this inquiry lab, pass out the background information to your class and read together.

INVESTIGATION 1

Investigation 1 is designed to help students determine which of three solutions is the best for the efficient dehydration of apple slices. The solutions to be tested are commercially prepared light corn syrup, a concentrated salt-water solution, and tap water. The syrup will have a sugar concentration of approximately 75%.

> NOTE: In all Investigations, BE CAREFUL to use only clean, uncontaminated containers since students will be tasting the products.

Upon completion of this Investigation, the students should fill out the Data Chart. You may wish to use the chart as the basis for class discussions. In the discussions, emphasize that color and texture are important to consumers. People are not likely to buy processed apples that appear foreign in color and texture.

In these Investigations, students will find that while tap water, salt water, and syrup produce no adverse effects on color and texture, only one of the agents will have the most acceptable overall results. Tap water often produces a weight gain in the fruit, thus it will not be considered in the Investigations. Both salt water and syrup produce satisfactory weight loss, but salt water imparts a taste that is unacceptable. Conversely, sugar which passes into the apple from the corn syrup complements the natural sugar of the apple.

Although not listed on the students' charts, another factor ARS scientists considered was toxicity. You can explain that there are other solutions such as arsenic chloride, copper sulfate, and butanol that also cause efficient osmotic-dehydration. They, however, are not used because of their toxicity.

INVESTIGATION 2

In this Investigation, students are to determine the effect of time on dehydration of apple slices. The percentage of weight loss for the slices soaked in the corn syrup for 24 hours will be greater than those soaked for 30 minutes, as in Investigation 1.

INVESTIGATION 3

This Investigation deals with solute concentration and the effect it has on osmotic-

dehydration. Before giving students this Investigation, prepare three serial dilutions of the syrup as follows:

1. Pour twice the amount of syrup normally needed by the entire class into a large beaker. For example, if there are six student teams in the class, you will need 2 x 6 (number of student teams) x 4 ounces (113 ml) (the capacity of one jar), or 48 ounces (1360 ml). This will be Solution 1 with a sugar concentration of approximately 75 percent.

2. Pour half of Solution 1 into another large beaker. To this solution add an equal volume of water. This will be Solution 2. Its sugar concentration will be approximately 43 percent. Now pour half of this mixture into a third beaker and set aside for Step 3. This will be Solution 3.

3. Take Solution 3 from Step 2 and add an equal amount (by volume) of water to it. This sugar concentration will be approximately 23%. Pour half of this Solution into another beaker and save for use as Solution 4, should you decide to make further dilutions (the next dilution would be approximately 12%, and the one after that, approximately 6%).

The apple slices soaked in Solution 1 will show the greatest weight loss.

INVESTIGATION 4

Students will prepare an emergency water purifier in this Investigation. Make the purifier from sheets of cellulose acetate, obtainable at most science material supply houses. Because students will be tasting the osmotically hydrated beverage, the marbles which keep the cellulose acetate bag submerged in the salt solution should be clean.

SUGGESTED READING

Food Technology, Ponting, J. D., Watters, G. G., Forrey, R. R., Jackson, R., Stanley, W. L., "Osmotic Dehydration of Fruits", Vol. 20, No. 10, pp. 125-128, Oct. 1966, reprint. A detailed review of the Osmovac Process complete with charts and graphs. Recommended for teachers and senior high students.

TO THE STUDENT

Since ancient times, our ancestors have been concerned with storing and preserving food supplies. Because of wars, famines, and droughts, we long ago realized the need to have an extra supply of food on hand at all times. To keep this food from rotting and spoiling, it had to be handled properly - - for example, it had to be protected from moisture which can cause grains to mildew and from excessive heat which encourages the growth of organisms which can spoil meat and cause fruits to rot.

Over the years, many techniques have been invented for improving the quality and safety of our food supply. Canning, pickling, smoking, and freezing are familiar examples. Unless you are a hiker or a camper, you may not be familiar with another important technique: drying. Early processes depended simply on the sun to do the drying. This technique is still one of the most widely used methods to preserve food -- for example, drying grapes to make raisins and drying plums to make prunes.

ARS scientists at the Western Regional Research Center have recently developed a more modern system for drying food, however. To understand how it works, you will first have to understand the biological principle of diffusion. If you don't, try this mini-investigation: go to the back of the classroom while someone opens a bottle of a strong-smelling solution in the front of the room, e.g., perfume or aftershave lotion. Are you able to smell the odor immediately or after several minutes have passed?

Here is what's happening: before the bottle was opened, there probably were no odor molecules of this type in the room. Gradually the molecules moved further and further away from the open container until they reached your nose.

The motion of each of these odor molecules was random. They moved both out into the room and back into the bottle. The net effect of this random movement was that more molecules moved from regions of high (in the bottle) to regions of low (in the room) odor-molecular concentration. This tendency for molecules to spread from regions of higher to lower concentration is called diffusion. If it continues, the concentration will eventually become the same everywhere in the room.

When molecules diffuse from one area to another through a membrane, this special case of diffusion is called osmosis. Osmovac, the drying technique developed by ARS scientists, is based on this principle of osmosis. In the process, the food products are osmotically dehydrated (water is removed).

Before you read further, make a literature search in your classroom or library on osmosis. Important concepts and terms are: cell wall membrane, selectively permeable (semi-permeable means the same thing), solute, solvent, regions of high and low solvent/solute concentration, and dehydration.

OSMOVAC

After osmotic drying, you can eat the food immediately. Or you can treat it further with freezing, air-drying or vacuum-drying. In the Osmovac process developed at WRRC in Berkeley, California, the product is vacuum-dried.

Food dried by other processes often turns a brown, unappetizing color. This is caused by an enzyme which scientists have labeled polyphenol oxidase. In the normal Osmovac process, this enzyme is inhibited. Since browning does not occur in Osmovac, good color can be retained in the dried product, and chemicals which prevent browning do not have to be used. Drying methods in which high temperatures are used also damage the color and flavor of the food. High temperatures are not used in Osmovac. Another advantage of Osmovac involves taste. As water diffuses from the fruit by osmosis, some of the acids in the fruit also are removed. This lower acid content produces a taste which is sweeter than the taste of air-dried fruit, thus making the dehydrated product suitable as a pleasant snack food.

A potential use of Osmovac products may

be in the dry cereal industry. Vacuum-drying of fruit pieces which have already been partially dehydrated by osmosis preserves the natural color and flavor of the fruit. Rehydrate (put back some of the moisture) with cold milk and the fruit or berry explodes with a burst of fresh fruit flavor when you bite into them.

These dried fruit slices one day also may find use in camping supplies, in chips or bits, in syrups for dessert toppings, in stuffing mixes, and in many other ways not yet dreamed of.

As you perform these Investigations, you will trace several of the steps taken by ARS scientists to determine the most favorable conditions for the osmotic-dehydration of fruit. You will determine the best solute, and then investigate the effects of solute concentration and time on the drying process.

INVESTIGATION 1 - SOLUTE EXPLORATION

MATERIALS PER TEAM

1/4 apple
1 paring knife
1 balance scale
3 jars with lids -
110 to 170 ml (4 to 6 oz.)
110 to 170 ml light
corn syrup
25 to 35 gm NaCl (table salt)
110 to 170 ml tap water
1 pair of tweezers
6 paper towels
1 large beaker

PROCEDURE

1. Cut two slices, each 4 mm thick (the thickness of 2 nickels), from the quartered apple. Remove the outer skin. Weigh and record the combined weight of the two slices.
2. Place both slices into a 110 to 170 ml jar. Cover the apples with syrup. Bring syrup as close to the top of the jar as you can without spilling over. Replace the jar's lid tightly and record the time.
3. Now, prepare the salt solution for Step 4. Add 20% sodium chloride (1.0 gram of salt for every 5.0 ml of water) to the quantity of water it takes to fill one of the glass jars. Stir the solution until the salt is dissolved.
4. Repeat Step 1. After placing the apple slices in the second jar, pour the salt solution over them, again bringing the liquid as close to the top of the jar as possible. Cap the jar tightly and record the time in your notebook.
5. Prepare and weigh two more apple slices as in Step 1. Don't forget to remove the skin. Put the slices into the third jar. This time, add plain tap water and cover the jar. Record the time.
6. After each group of apple slices has been in their respective solutions for 30 minutes, remove them using the tweezers, allow to drain, then quickly rinse (2 to 4 seconds) them in a large beaker of tap water. Following the rinse, place the slices between two paper towels for a few seconds to absorb any excess moisture from the rinse.
7. Weigh and record each set of apple slices.
8. After you have weighed all the apples, complete the attached chart.
9. Clean your lab area.

QUESTIONS FOR THOUGHT

1. Why do you think it is important to remove the apple's skin before soaking?
2. What part of the apple acts as the semi-permeable membrane?
3. If you received a contract from a camping distributor for dried backpacking food, which of the three solutions would you select for your system? What are the reasons for your selection?

EXTENDING THE INVESTIGATION

1. Use different solutions for the osmotic-dehydration of apple slices.

   Here are some examples:

   a saturated solution of sugar in water
   salad oil
   baking soda and water
   pancake syrup
   honey and water

   Does your solution satisfy the requirements of an efficient dehydrating agent, i.e., does it produce a significant weight loss? Is it nontoxic? Does it leave a pleasant taste and not discolor the apple in any way?

2. Repeat Investigation 1, but substitute other fruit pieces for the apple slices. Do bananas dehydrate as well as pears?

INVESTIGATION 2 - TIME AND WATER LOSS

MATERIALS PER TEAM

1 balance
1/4 apple
1 paring knife
1 jar with lid -- 110 to 170 ml (4 to 6 oz.)
110 to 170 ml light corn syrup
1 pair of tweezers
2 paper towels
1 large beaker

PROCEDURE

1. Slice two 4 mm thick apple sections from the 1/4 apple. Remove the skin and weigh the two sections. Record their combined weight in your notebook.

2. Place the apple slices in the jar. Pour the syrup over the pieces, bringing it as close as possible to the top of the jar. Tightly replace the jar's lid and record the time.

3. Place the jar where it will not be disturbed for 24 hours.

4. Keep at room temperature.

5. After 24 hours, remove the samples, drain, rinse, pat dry, and weigh. Record your results.

6. Clean your lab area.

QUESTIONS FOR THOUGHT

1. Calculate the percentage of weight loss after 24 hours of soaking. According to your results from Investigations 1 and 2, does time influence the water loss? If so, how?

2. You own a processing plant for dehydrating fruits and you want to reuse your syrup as much as possible. Would you soak the fruit for long or short periods of time? (Hint: Which solution will be more dilute after one use?)

3. As Plant Manager, one of your responsibilities is to see that nothing is wasted. What might you do with syrup that can no longer be recycled as an osmotic-dehydrating agent?

EXTENDING THE INVESTIGATION

1. Set up an experiment to determine whether there is a certain time beyond which the apples will stop dehydrating. Will they ever regain water after a certain amount of time has elapsed?

2. Determine which of the following will lose the greatest percentage of their weight after 24 hours: pear, plum, or strawberry. Can you think of other fruits to test?

INVESTIGATION 3 - SUGAR CONCENTRATION AND WATER LOSS

MATERIALS PER TEAM

1 balance
1/4 apple
1 paring knife
3 jars with lids --

110 to 170 ml
1 pair of tweezers
110 to 170 ml of 75% light corn syrup
110 to 170 ml of 43% light corn syrup
110 to 170 ml of 23% light corn syrup
6 paper towels
1 large beaker

PROCEDURE

1. Prepare and weigh two 4 mm thick apple slices. Record their combined weight in your science notebook.
2. Place the apples in a jar and cover them with the 75% syrup solution. Be sure to bring the syrup close to the top of the jar without overflowing. Replace the lid and record the time.
3. Repeat Step 1 two more times. After placing the apple slices in their respective jars, pour the 43% syrup solution in one jar and the 23% solution in the other. Replace the lids tightly on both jars. Record the time.
4. After 30 minutes, drain, rinse, and pat the apple slices dry. Weigh them to determine if there has been any weight change. Record your results.
5. Clean your lab area.

QUESTIONS FOR THOUGHT

1. Were there any noticeable differences in the texture of the apple slices among syrup dilutions 1, 2, and 3? Did one seem more spongy than the others? How do you explain this? Were there any differences in taste?
2. If you were the Plant Manager of a factory where fruits were osmotically dried for packaging, which of the concentrations used in Investigation 2 would you select? Why?
3. If the price of sugar were to increase sharply, what might you do to ease the burden of the increased costs without affecting the quality of your product?

EXTENDING THE INVESTIGATION

1. Design an experiment to determine the percentage of weight loss for apple slices soaked in a low concentrated corn syrup solution for 24 hours.
2. ARS scientists have discovered that agitating (stirring) the fruit sections affects the percentage of weight loss. Determine what effect agitation has on osmotic-dehydration through an Investigation of your own making.
3. You manage a factory in a desert area of the U. S. The temperatures there are 32° C. or higher. Will your products dehydrate more or less than those of a factory in the northern reaches of Alaska where the temperature averages 4° C.? (Both factories are poorly insulated.)

SUGGESTED READING

Process Biochemistry, Ponting, J.S., Dec. 1973, reprint, "Osmotic Dehydration of Fruits -Recent Modifications and Applications." Applications of osmotic dehydration are discussed, particularly the Osmovac process for producing low-moisture food products. Optimum operating conditions are also discussed. Excellent article for both teacher and student.

Food, Processing and Marketing, Ponting, J. D., Watters, G. G., Forrey, R. R., Jackson, R., Stanley, W. R., Feb. 1966 reprint, "More Flavorful Dried Fruit." Describes Osmovac and its variations, potential applications and advantages. Recommended for both teacher and student.

Journal of Science of Food and Food Agriculture, Camirand, W. R., Forrey, R. R., Popper, K., Boyle, F. P., Stanley, W. R., Vol. 19, pp. 472-474, Aug. 1968, "Dehydration of Membrane-Coated Foods by Osmosis." Describes method of membrane-coated dehydration and shows results of foods processed.

Recommended for teachers and senior high students.

INVESTIGATION 4 - EMERGENCY WATER PURIFIER

MATERIALS PER TEAM

113 gm (4 oz.) concentrated orange juice
1 20 cm x 20 cm of cellulose acetate
1 300 to 500 ml jar with lid
100 gm sodium chloride
300 to 500 ml tap water
1 balance scale
2 uncontaminated marbles

PROCEDURE

1. Prepare a salt solution by adding 3.5% salt (3.5 grams of salt for every 100 ml of water) to the tap water. Stir until the salt is dissolved.
2. Place the cellulose acetate sheet into the jar with the salt solution in such a manner as to form an open-mouth bag. Be careful to leave an overlap of about 3 cm around the top edge of the jar (to fasten the cap down on later). See Diagram 1.
3. Carefully weigh the bag you have just formed by placing the marbles inside. Now, slowly pour the liquid orange juice concentrate into the bag. It is important that the upper level of the orange juice is below the top level of the salt water solution in the jar. Seal the jar by securing the lid over the 3 cm cellulose acetate border.
4. Allow this apparatus to stand for 48 hours. When the time has passed, check the orange juice concentrate by tasting.
5. Clean your lab area.

QUESTIONS FOR THOUGHT

1. If you were planning to cross the ocean on a raft, how might the results of the Investigation prove useful to you?
2. What other concentrates might you use as part of your emergency water purifier?
3. Under what other conditions might this system prove useful to you?

EXTENDING THE INVESTIGATION

1. Design an experiment to see if extending the soaking time will further dilute the concentrate with drinkable water.
2. Repeat Investigation 4, but, instead of orange juice, use a different concentrate. How do the results compare?

SUGGESTED READING

Nature, Popper, K., Camirand, W. M., Stanley, W. L., Nury, F. S., Vol. 211, No. 5046, pp. 297-298, July 16, 1966, "Osmotic Emergency Purifier of Sea Water." Describes method by which a sustaining beverage is obtained from sea water and contaminated water by dialysis. Suggested reading for teachers and senior high school students.

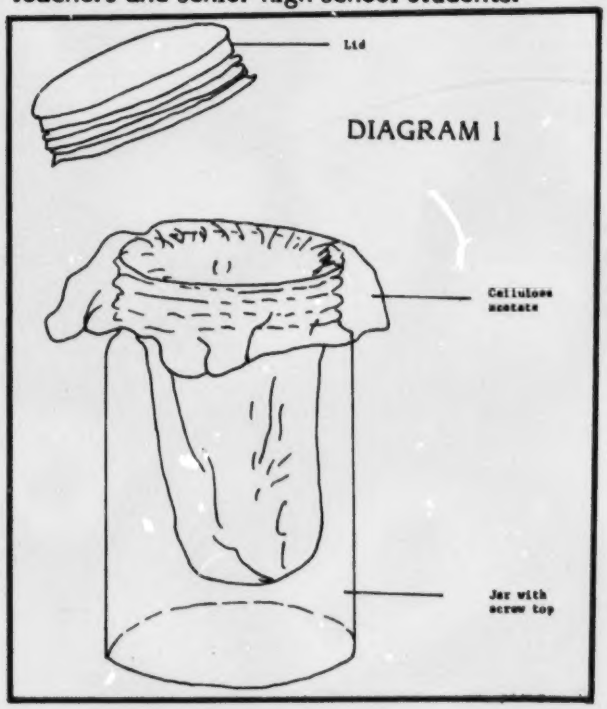

DIAGRAM 1

Food Samples	SOLUTIONS		
	Tap Water	Saturated Salt Solution	Corn Syrup
Initial Color / Color After Removal			
Initial Texture / Texture After Removal			
Initial Taste / Taste After Removal			
Weight Before Placing in Solution / Weight After Removal			
Percent Weight Loss			

INVESTIGATION 1
DATA CHART

science study aids

are a series of supplementary investigative materials for use in secondary science classes, grades 7 - 12. The materials are based on federal and private research programs. They are written by secondary science teachers working with scientists at research facilities throughout the country. Before being published, they are tested in the laboratory and in classrooms of cooperating teachers.

Several times during the year, new SSA's are developed. If you want to be notified of their availability, request that your name be added to Wordwork's mailing list. Because we cannot provide enough copies for students, we have designed SSA's so that teachers can easily reproduce the student portion for their classes.

We hope that you find the Science Study Aid Series a valuable supplement to your science curriculum. We welcome you comments on the SSA's that you receive.

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